Range of temperature.	NiS.	Ag_2S.
$-182°$ to $+15°$	0·0972	0·0568
15° ,, 100°	0·1248	0·0737
15° ,, 324°	0·1333	0·0903

The mean value for the specific heat of silver sulphide is less than that for nickel sulphide throughout, but little can be deduced from the results till the influence of temperature on the specific heat of sulphur is known.

"Preliminary Note on the Relationships between Sun-spots and Terrestrial Magnetism." By C. CHREE, Sc.D., LL.D., F.R.S. Received December 18, 1902,—Read January 22, 1903.

(From the National Physical Laboratory.)

I have been engaged during the last two years on an analysis of the magnetic results obtained at Kew Observatory (now the National Physical Laboratory), during an 11-year period, 1890 to 1900. The work has been much interrupted, and is still incomplete. Amongst the points dealt with is the inter-relationship between sun-spot frequency and magnetic phenomena, and, as this has recently been engaging attention elsewhere, I have decided to put certain of my results on record at once. It has long been known from the researches of Balfour Stewart, Ellis, and others, that there is a close connection between the times of occurrence of greatest sun-spot frequency and largest amplitude of the diurnal inequality of magnetic declination and horizontal force. I have investigated whether the numerical relationship between the phenomena can be adequately represented mathematically in a simple way.

A convenient basis for the investigation was presented by the publication by Professor Cleveland Abbe in the 'U.S. Monthly Weather Review,' for November, 1901, of a table of sun-spot frequencies as calculated by Wolf and Wolfer for a very long series of years. After I had carried out all the calculations, Wolfer himself published a similar table* embodying his latest corrections. The differences from Abbe's table are trifling, and mainly confined to two years (1891 and 1892). I judged it best, however, to revise the whole of my arithmetic, so as to employ Wolfer's own most approved figures. In the following remarks S represents Wolfer's value for the sun-spot frequency. The above-mentioned table gives the mean S for each month and for each year.

The magnetic quantity selected for comparison is the mean monthly "range," meaning thereby the difference between the greatest and

* 'Met. Zeitschrift,' May, 1902 p. 195.

least of the twenty-four hourly values in the mean diurnal inequality for the month in question, based on the five *quiet* days selected for the month by the Astronomer Royal. Calling this quantity R for any particular magnetic element, I tentatively assumed

$$R = a + bS \quad\quad (1),$$

with a and b constants. I grouped together the 11 Januarys, the 11 Februarys, and so on, of the 11-year period, and determined a and b by least squares for each of the resulting 12 groups. There being only 11 years' data, the calculated values doubtless are appreciably affected by quasi-accidental irregularities, but there is so striking a resemblance between the more conspicuous features of the results found for the declination, inclination and horizontal force as to justify the conclusion that the phenomena are *bonâ fide.* Full particulars will be given later. At present it will suffice to record the mean values found for the a and b of the formula for three groups of months —viz. :—

Winter, comprising November to February,
Equinox ,, March, April, September, October, and
Summer ,, May to August.

The results are as follows :—

Table I.

	Declination.		Inclination.		Horizontal force. (Unit $1\gamma \equiv 10^{-5}$ C.G.S.)		Vertical force. (Unit $1\gamma \equiv 10^{-5}$ C.G.S.)	
	a.	*b.*	*a.*	*b.*	*a.*	*b.*	*a.*	*b.*
Winter ...	3′·23	0′·0323	0′·63	0′·0105	10·5	0·161	7·0	0·032
Equinox ..	7·32	0·0478	1·26	0·0147	23·5	0·221	17·2	0·026
Summer ..	8·91	0·0428	1·61	0·0137	30·6	0·190	22·7	0·035
Mean.....	6·49	0·0410	1·17	0·0130	21·5	0·191	15·6	0·031

As is obvious from (1), a represents the amplitude of the range corresponding to a total absence of sun-spots. During the eleven years dealt with, Wolfer's mean monthly values for S varied from 0·3 to 129·2, the mean being 41·7.

To bring out more clearly the similarity of the results for the declination, inclination and horizontal force, I have represented the mean value of b for the 12 months in each element by 100. The corresponding values for the three seasons are, then, as follows :—

Table II.

	Winter.	Equinox.	Summer.
Declination	79	117	104
Inclination	81	113	106
Horizontal force.. ...	85	116	99

In obtaining these figures I have retained a figure in the value of b beyond that recorded in Table I.

Tables I and II will suffice to bring out one of the most important points established, viz., that b is certainly different from one month to another, and is, for all the elements except the vertical force, decidedly larger at the equinoxes (more especially it would appear at the spring equinox) than at other seasons. This means that the equinoxes are the seasons at which the amplitude of the diurnal inequality, when considered *absolutely*, is most dependent on the sun-spot frequency. When we take into account, however, the difference between the ranges of the diurnal inequalities at different seasons of the year, we find that winter is the season when sun-spot frequency is *relatively* most important. This will be recognised on reference to Table III, remembering that a represents the range corresponding to a total absence of sun-spots, while $a + 41{\cdot}7\,b$ is the range corresponding to a sun-spot frequency of 41·7, this being, as already mentioned, Wolfer's mean value for the 11 years in question.

Table III.

Values of $41{\cdot}7b \div a$.

	Declination.	Inclination.	Horizontal force.	Vertical force.
Winter	0·42	0·69	0·60	0·19
Equinox	0·27	0·49	0·39	0·06
Summer	0·20	0·35	0·26	0·07

Table III serves also to bring out another important result, viz., that the influence of sun-spot frequency on the amplitude of the diurnal inequality is very much less for the vertical force than for the three other elements considered.

A recent interesting paper by Rajna* shows that the idea of a linear relationship between diurnal magnetic range and sun-spot frequency has already been applied by at least two previous investigators, Rajna and Wolfer. They seem, however, to have applied it only to mean annual values, and to have considered declination only. Rajna, dealing with declination data, observed at Milan over the long period 1836 to 1901, applies a formula of type (1) to what he calls the "medie annuali dell' escursione diurna."

The value he finds for b is 0′·047. He mentions that in an earlier similar investigation, including declination data from several stations, Wolfer obtained the value 0′·040.

I am uncertain as to the precise meaning of Rajna's "medie annuali," but it certainly is not quite the same thing as the mean range in Table I, so that the results are not absolutely comparable.

* 'Rendiconti del R. Ist. Lomb.,' Serie II, vol. 35 1902.

Another recent and able paper bearing on the subject appears in the last published volume of the French Bureau Météorologique, which has just come into my hands. The author, Mr. Alfred Angot, has anticipated me in applying a formula of type (1) to the individual months of the year; but he treats of the amplitude, not of the diurnal range as a whole, but of that of the coefficients of the several terms of the Fourier's series into which the diurnal inequality can be analysed. The paper treats only of the declination—dealing with data from ordinary days at Parc St.-Maur, Greenwich and Batavia—but the author expresses his intention of considering in the future the horizontal force.

A special feature of the present investigation is that the magnetic data are derived exclusively from magnetic *quiet* days. This suggests at once a query and a criticism, a query as to why one did not employ corresponding sun-spot data confined to the magnetically quiet days, a criticism that as the two sets of data employed do not absolutely correspond, the comparison actually made may be misleading.

As to the query: Wolfer, it is true, publishes at regular intervals in the 'Met. Zeitschrift' *provisional* sun-spot frequencies for each day. These figures are, however, presumably inferior in certainty to the final figures he has embodied in his table after consulting all available sources of information. The vital consideration, however, is that at certain seasons of the year there are a number of days for which, owing to the absence of observations, Wolfer has no provisional sun-spot data. With information lacking for two or three out of the five quiet days of a month there would have been a very undesirable amount of uncertainty. As to the criticism, it would be difficult to meet it if it could be held that the enhanced magnetic activity existing at the earth's surface at times of sun-spot maxima is due directly to electrical disturbances in the sun, each disturbance being limited to regions where sun-spots exist, and only those disturbances being effective which happen to be at the moment on the half of the sun visible from the earth. At present I shall only mention the following fact:—I had monthly sun-spot frequencies calculated from Wolfer's *provisional* figures, employing only the five "quiet" days selected for each month by the Astronomer Royal. The mean sun-spot frequency thence deduced for the eleven years (1890 to 1900) differed from the corresponding result given by all Wolfer's days by less than one-fifth of 1 per cent. It is hardly necessary to point out that this fact has an important bearing, not only on the point immediately under consideration, but also on the further question as to the true nature of the connection between sun-spots and magnetic storms.